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Solvay Natural Gas Boiler Addition, PSD Permit Application – Response to EPA Comments on GHG BACT Analysis

PREPARED FOR:
SOLVAY SODA ASH
JOINT VENTURE

PROJECT NO. 170-12-2
AUGUST 12, 2013

AIR SCIENCES INC.

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Project No. 170-12-2

Mr. Donald J. Law
U. S. Environmental Protection Agency, Region 8 Air Program
1595 Wynkoop Street
Denver, CO 80202-1129

Subject: Solvay Natural Gas Boiler Addition, PSD Permit Application – Response to EPA Comments on GHG BACT Analysis

Dear Mr. Law:

On August 9, 2012, the Solvay Soda Ash Joint Venture, Green River Soda Ash Plant (Solvay) submitted a Best Available Control Technology (BACT) analysis for greenhouse gas (GHG) emissions for its proposed installation of a 254 MMBtu/hr natural-gas-fired package boiler for U. S. Environmental Protection Agency, Region 8 (EPA) review. The boiler is to be installed at the existing Solvay facility, which is located 20 miles west of Green River, Wyoming.

On July 22, 2013, EPA asked that Solvay clarify or provide additional information to EPA regarding the GHG BACT analysis. The attachments to this letter provide Solvay's response to EPA comments.

Please contact Tim Brown of Solvay (307-872-6570) or me (971-271-5314) with any questions you might have regarding these responses and the GHG BACT analysis.

Sincerely,

Tim Martin
Senior Atmospheric Scientist
Air Sciences Inc.

Attachments

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Cc: Tim Brown – Solvay
David Hansen – Solvay
Cole Anderson – Wyoming DEQ
Andrew Keyfauver – Wyoming DEQ
Rodger Steen – Air Sciences Inc.

Attachment A – Solvay Response to EPA's July 22, 2013, Comments

Solvay Response to EPA's July 22, 2013, Comments (E-mail from D. J. Law, EPA Region 8, to Tim Brown, Solvay)

Summary of EPA Comment #1 – Carbon Capture and Storage (CCS) Comment: EPA suggests that Solvay provide the cost of CCS compared to the total cost of the project without CCS. The Sinclair Refinery used this argument to successfully justify elimination of CCS as BACT.

Solvay Response Comment #1: In Solvay's August 9, 2012, GHG BACT analysis, Solvay asserted that CCS is expected to be infeasible as an available control option because of lack of availability of CO_2 sinks to Solvay and general EPA guidance on BACT for a small gas-fueled boiler. Nevertheless, per July 25, 2013, EPA verbal comment, EPA considers CCS as technologically feasible. So, Solvay is providing an additional evaluation of the economic feasibility of CCS as part of Step 4 of the GHG BACT analysis. The conclusions of this analysis indicate that the costs for retrofit for CCS are unreasonably high, and CCS is eliminated through cost considerations as a BACT option. Recently, the Sinclair Refining Company in Wyoming[1] successfully argued that the 0.71 ratio of cost for CCS to project cost without it was cost prohibitive, and CCS was eliminated as BACT. Solvay provides a similar cost analysis herein.

CCS involves the capture of the CO_2 from the process at the facility, compression and transportation of the captured CO_2 (truck, pipeline, etc.), well drilling if a well is not already available, and underground storage of the captured CO_2. To conservatively estimate CCS costs for the natural gas boiler project, Solvay is utilizing cost estimates here from another similar project at the Solvay facility, referred to as the MEA CO_2 Extraction Project (MEA project). For the MEA project, Solvay considered the cost of capturing/removing CO_2 (post-combustion) from one of its two coal-fired boilers at the facility. This MEA project cost included CO_2 capture, but did not include compression, transportation, and storage of CO_2, therefore providing a low-end (conservative) estimate of CCS costs for the natural gas boiler project.

Union Engineering estimated costs for removal of ~118,000 tpy CO_2 from the coal boiler flue gases with a 10.6 percent concentration of CO_2 in the exhaust stream. For comparison, the CO_2 emissions available from capture from Solvay's natural gas boiler are ~130,000 tpy CO_2 at capacity with CO_2 flue gas concentrations around six percent. The MEA project was designed to remove approximately 90 percent of the mass of CO_2 of the current boiler project, so the projects are similar in size. Therefore, the MEA cost is a reasonable substitute for the current boiler project cost.

[1] Sinclair Wyoming Refining Company, Sinclair Refinery, Permit No. PSD-WY-000002-2011.001, March 21, 2013.

When the MEA project costs are applied to Solvay's natural gas boiler project, there are several reasons why the MEA project costs are on the low side when utilized as an estimate of CCS costs for Solvay's natural gas boiler project:

- The MEA costs pertain to CO_2 capture and do not account for downstream CCS activities such as compression, transportation, and storage.
- There is more CO_2 in the natural gas boiler exhaust (~130,000 tpy CO_2 for the gas boiler compared to ~118,000 tpy CO_2 from the coal boilers per the Union Engineering Bid).
- The natural gas boiler exhaust CO_2 concentration is lower than the CO_2 concentration from the coal boilers; thus, it would require more extraction solvent and would cost more to remove CO_2 from the lower-concentration exhaust.

Attachment B, Page 1 provides Solvay's total cost estimate of $25,675,625 for the MEA CO_2 capture project. These total project costs include the costs of materials, equipment, construction, services, operating expenses, and project contingencies. Attachment B, Pages 2 through 26, provide a budget quote from Union Engineering for the CO_2 capture equipment package whose costs are included in the total MEA project costs.

As provided in Attachment C, Solvay estimates the total cost of the natural gas boiler project at $12,506,350. This is the same cost used by management in the past to determine the viability of the project for production economics purposes.

Therefore, the estimated CCS costs for the natural gas boiler project ($25,675,625) are 2.05 times higher than the total costs of the natural gas boiler project ($12,506,350). For the Sinclair Refinery project, EPA determined that a post-combustion CCS cost to project cost ratio of 0.71 was financially prohibitive due to its overall cost as a GHG control strategy. Solvay's CCS cost to project cost ratio of 2.05 is nearly three times higher than the Sinclair Refinery project. Therefore, Solvay concludes that CCS is financially prohibitive and does not represent BACT for its natural gas boiler project.

Summary of EPA Comment #2 – Additional Discussion Regarding Table #4: Please provide additional discussion regarding the entries in Table #4 of Solvay's August 2012 submittal, which are listed as not feasible (i.e., the "no" entries). In addition, clarification on the positive-pressure nature of the boiler would be helpful in the process description to help with the technical infeasibility of minimization of air infiltration.

Solvay Response Comment #2: Table #4 of Solvay's August 9, 2012, GHG BACT analysis provides a listing of possible energy efficiency improving methods (and CCS), their feasibility, and whether these methods are considered further in BACT analysis. In Table #4, Solvay has listed four methods as not feasible/not relevant: 1) increase the amount of refractory lining, 2) minimization of air infiltration, 3) minimization of gas-side heat transfer surface deposits, and 4) CCS.

As addressed in the August 9, 2012, BACT analysis, it is not feasible to increase the amount of refractory lining because the lining serves a performance function for the boiler and an increase in the amount of refractory lining would require boiler redesign, so no further discussion is provided here. As discussed in Comment #1 above, EPA considers CCS as technically feasible and no further discussion is provided here.

Additional discussion regarding minimization of air infiltration: In the August 9, 2012, BACT analysis, minimization of air infiltration is not listed as feasible because the boiler operates under positive pressure. Positive pressure is a pressure within a system that is greater than the environment that surrounds that system. Consequently, if there is any leak from the positively pressured system, it will egress into the surrounding environment.

For a boiler, a positive pressure is created in a boiler furnace when the intake fan airflow for the boiler is greater than the exhaust airflow from the boiler. Solvay's natural gas boiler will operate at positive pressure (18.51" W.C.) as indicated in Solvay's August 9, 2012, GHG BACT analysis (Appendix B, Coen Burner Bid); the boiler will operate at a pressure higher than the environment surrounding the boiler. Therefore, when the boiler is operating, the higher pressure air from the boiler will exert outward forces from the boiler, which would eliminate/minimize air infiltration into the boiler.

Additional discussion regarding minimization of gas-side heat transfer surface deposits: In the August 9, 2012, BACT analysis, the minimization of gas-side heat transfer surface deposits is listed as not relevant to gas firing because natural gas contains no long-chain hydrocarbons that have the potential to condense onto the boiler walls.

Attachment B – Solvay MEA Project Cost Estimates and Union Engineering Bid

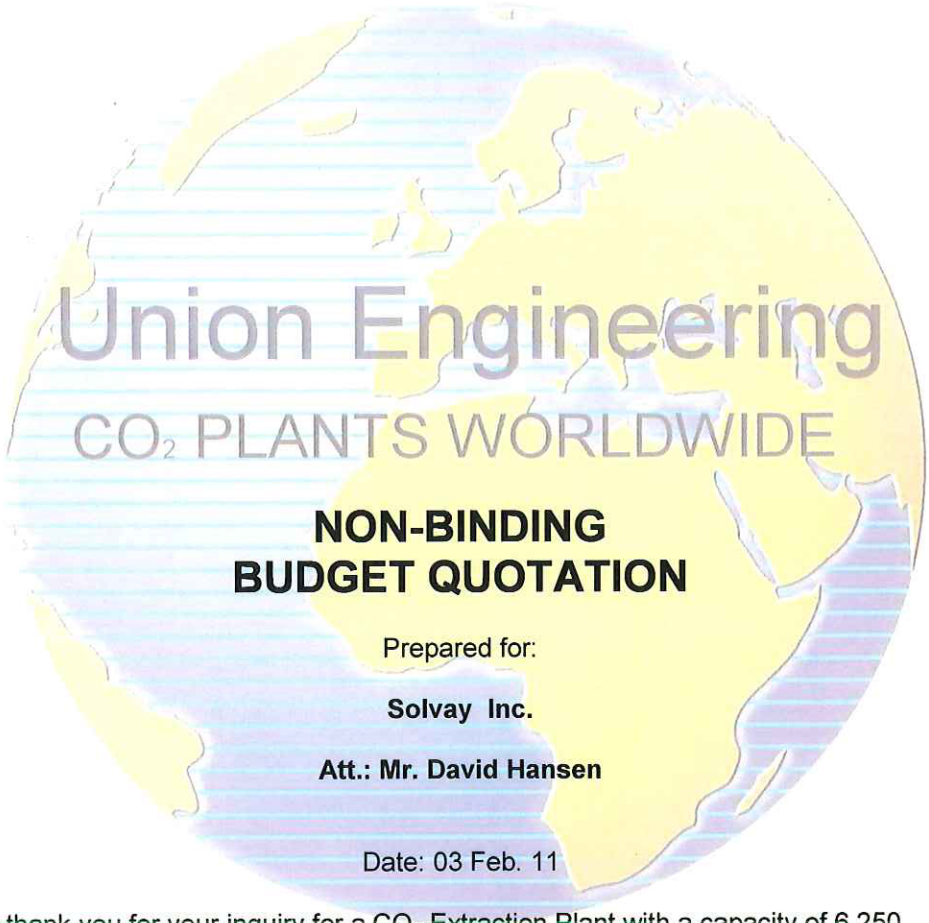
SOLVAY CHEMICALS, INC.
MEA CO2 EXTRACTION PROJECT

BUDGET ESTIMATE 1/8/2011

EQUIP. PO NO.	DESCRIPTION	BUDGET VALUE
	Materials	
03-001	Concrete Reinforcing (Rebar only, incl. piers)	$100,000
03-002	Concrete Embedded Items (Anchor Bolts, Curb Angle, etc)	$30,000
03-003	Concrete Block (incl. fixtures)	$70,000
05-001	Ductwork (S.S.)	$400,000
05-002	Structural & Miscellaneous Steel	$300,000
05-005	Metal Decking (3", galvanized)	$7,500
13-002	Siding & Roofing (incl. girts & purlins)	$100,000
13-003	Doors & Hardware	$30,000
15-001	Piping (incl. valves, fittings & shop fab.)	$125,000
15-002	Pipe Insulation	$40,000
	TOTAL	**$1,202,500**
	Equipment	
	MEA Equipment Package - Union Engineering	$6,072,300
TK-1	MEA Storage Tank - TBD	$30,000
	Carbon Handling System - TBD	$180,000
	Spent Carbon Handling System - TBD	
	HVAC Equipment (for Electrical Bldg)	$60,000
	Monorails, Jib, Hoists & Trolleys (2)	$40,000
	Spare Parts (Repairable) - Union Engineering	$115,700
	Cooling Tower	$750,000
16-001	Electrical - Process (materials & equipment)	$200,000
16-002	Electrical - Infrastructure (materials & equipment)	$2,000,000
16-003	Electrical - Rework (materials & equipment)	$100,000
17-001	Instrumentation & Controls (materials & equipment)	$250,000
17-002	DCS Upgrades	$100,000
	TOTAL	**$9,898,000**
	Construction Contracts	
10-001D	Demo & Site Prep	$100,000
10-001	Drilled Pier Construction (30 piers @ 18" - 36" dia x 30 ft., incl. concrete, 575 cu yd)	$150,000
10-002	Foundation Construction (incl. concrete, 1,000 cu yd)	$800,000
10-003	Mechanical/Structural Construction (incl. concrete, 150 cu yd)	$5,000,000
10-006	HVAC Construction (incl. materials)	$90,000
10-007	Siding & Roofing Construction	$50,000
11-001	Electrical Construction	$500,000
11-002	Instrumentation Construction	$250,000
12-001	QA/QC, Testing (Structural and Mechanical)	$25,000
12-002	QA/QC, Checkout (Electrical and Instrumentation)	$50,000
ECMS	Misc. Material, Equipment & Construction Requisitions	$20,000
SOLVAY	Misc. Material, Equipment & Construction Requisitions	$20,000
	TOTAL	**$7,055,000**
	TOTAL EQUIP, MAT'L & CONTRACTS	**$18,155,500**
	Services Contracts	
	Solvay Corporate Engineering & Testing	$250,000
	Preliminary Engineering (ECMS, etc.)	$75,000
	ECMS - Detailed & Final Engineering (Phase II) & Procurement Support (Phase III)	$900,000
	Detailed & Final Electrical Engineering	$100,000
	ECMS - Construction Management (Phase IV)	$900,000
	TOTAL	**$2,225,000**
	SUBTOTAL - BEFORE CONTINGENCY	**$20,380,500**
	SOLVAY - Overhead (0%)	$0
	Contingency (25%)	$5,095,125
	TOTAL CAPITAL COST	**$25,475,625**
	Operating Expenses	
	Spare Parts (Non-repairable)	$200,000
	TOTAL	$200,000
	TOTAL PROJECT COST	**$25,675,625**

UNION ENGINEERING

Reliable solutions by dedicated people



NON-BINDING BUDGET QUOTATION

Prepared for:

Solvay Inc.

Att.: Mr. David Hansen

Date: 03 Feb. 11

We thank you for your inquiry for a CO_2 Extraction Plant with a capacity of 6,250 kg/h, based on extraction from flue gasses and we hereby have the pleasure of submitting you our best offer:

Quotation No. QUO-07033-UUJB0H - CO_2 Extraction Plant,

Type EBU 6,250

We hope the enclosed quotation complies with your expectations and if you need any further information we shall be pleased to assist you.

Your contact person for this project will be Mr. Tage Frank Jensen, Sales Manager.

Telephone: +45 76 20 77 54
Fax: +45 76 20 78 39
E-mail: tfj@union.dk
Homepage: www.union.dk

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COMMERCIAL PART

Summary of Prices

Description	Price in EURO
CO_2 extraction unit, type EBU 6250	4,525,000 €
20 man week of supervision	146,000 €
Total Price[1]:	**4,671,000 €**

[1] Lump sum price FCA, Incoterms 2000 from US / Europe / China

Optional Scope of supply	Price in EURO
Spare parts for 2 years of normal operation	89,000 €

The prices quoted above are non-binding and should be considered budgetary since no detailed engineering has been performed.

The accuracy of the above prices is +/-15%.

Commercial Conditions

Time of Delivery:	9 months Ex works from receipt and acceptance of Letter of Credit and receipt of advance payment.
Terms of Payment:	20% advance payment on order 80% against irrevocable, confirmed Letter of Credit, payable: 1. 30% 2 months after ordering. 2. 45% at shipment 3. 5% against acceptance certificate.
Warranty:	12 months from signed Taking-Over Certificate, however, max. 18 months from date of the shipment. The guarantees cover replacement of parts showing abnormal wear and tear and of materials, which prove unfit for the respective purposes. Further, we supply components for remedying defects, if any. The guarantee does not cover labour for the replacement.
Confidentiality:	This quotation together with related information is to be considered confidential, and the quotation, whole or in part, shall not be handed over to third party without Union Engineering's written approval.

During the period of delivery the order will be subject to reservations as to industrial disputes and any other circumstances beyond the control of the parties.

We hope to be favoured with your kind order, which shall have our best attention, and we remain at your service with further details you might want.

Best regards,
Union Engineering a/s

Tage Frank Jensen
Sales Manager
Industrial Gases Group

Arne Ladegaard
Proposal Manager
Industrial Gases Group

TECHNICAL PART

Plant Design and Standards

Pipes and vessels

- Pressure vessels are manufactured according to ASME VIII with U-stamp
- Pipes, flanges and fittings are sized and designed according to ANSI.
- Materials according ASTM

Where third party inspection is required it will be performed by a notified body.

Motor specifications

• Insulation class		F with class B temperature rise
• Enclosure		TEFC / WP2
• Nominal voltage,	motors > 225 kW	4,16 kV AC
	Motors < 190 kW	480 V AC

Electrical specifications

- All skid mounted instruments are pre-wired to junction boxes prior to shipment.
- All electrical components are earthed to the panels.

Electrical motors

• Insulation class	F
• Protection grade	IP 55
• Nominal low voltage	400 VAC

Instruments

• Protection grade	IP 54 or 55
• Output signal	4-20 mA
• Control voltage	24 VDC

General technical information

Plant assembling

The plant will be delivered with the main components mounted on skids. Skid mounted equipment has all internal piping connections made prior to shipment. Some reassembling on site must however be foreseen.

Pipes for cooling water and instrument air are connected to individual components on the skid prior to shipment and are collected in one common pipe connection for each skid for easy installation on site.

Absorber and stripper will be delivered in four and two sections respectively for reducing transportation costs. These need to be welded and approved on site by customer

The skids and process towers are to be placed on levelled foundation and fixed to the foundation by means of anchor bolts or expansion bolts. Foundation templates for process towers are supplied 2 months before arrival of the towers.

Around each skid, floor trenches must be foreseen where to all drains will be led.

Interconnecting pipes

Pipe connections between skids and field equipment are not included in this scope. Hence the installation must be made on site after deliverance. Union Engineering will supply the customer with isometric drawings of the required interconnecting pipes. The pipes shall be in the following materials

• Pipes carrying feed gas	SS
• Pipes carrying flue gas scrubbing water	SS
• Pipes carrying MEA solvent	SS
• Pipes carrying wet CO_2 gas	SS
• Pipes carrying dry CO_2 gas and liquid	CS / low temperature CS
• Pipes carrying cooling water	CS
• Pipes carrying refrigerant	CS / low temperature CS
• Tubes carrying instrument air	SS/UV resistant plastic

Testing

Workshop test prior to shipment consisting of:

- Line walk. Control of mechanical installation of skid-mounted equipment according to P&I diagrams.
- Electrical test. Control of correct installation of junction boxes.
- Functional acceptance test (FAT) of control systems.
- Control of all instruments settings.
- Control of equipment authority approvals.

Painting.

- All plant skids will be painted according Painting System P1 or similar.

- Where required and when possible painting on internal skid equipment will be done before delivery. Painting touch-up on site must be foreseen.
- Equipment with insulation will only be primed.
- Stainless steel and other corrosion-resistant material surfaces will not be painted.
- Valves, pumps, etc. will be supplied in original painting from supplier.

Insulation

All pipes and vessels on the skids, which require insulation, will be insulated in our workshop according to Solvay specifications.

The insulation for hot equipment serves two purposes: heat conservation and personnel protection. For personnel protection surfaces will only be insulated if contact is possible during normal operation.

Process Design

Geographic and climatic conditions	
Wet bulb temperature	58°F / 14,4°C
Design Dry bulb temperature summer	94°F / 34,4°C
Design Dry bulb temperature vinter	-40°F / -40°C
Extreem design temperatures summer	104°F / 40°C
Extreem design temperatures (max./min.)	-45°F / -42,8°C
Wind speed (design)	Max. 100 mph / 44,7 m/s
Altitude	6240 feet / 1902 m
Seismic zone	None
Plant location	USA

Power supply	
Voltage (high / low)	4160 kV / 480 / 120 VAC
Frequency	60 Hz
Phases	3
Control voltage	24 VDC / (120 VAC)
Grid type	A, B, C net

Cooling water supply	
Inlet temperature	30 °C
Temperature difference	10 °C
Inlet pressure	3 bar g
Quality:	
Hardness	max. 6° dH
Cl^-	max. 100mg/l
SO_4^-	max. 500 mg/l
SiO_2	max. 200 mg/l
TDS	max 2.000 mg/l
Fe	max. 0,25 mg/l
Mn	max. 0,10 mg/l
Inhibitors for corrosion protection	-

Scrubbing water supply (Demin water)	
Inlet temperature	30 °C
Inlet pressure	2 bar g
Quality:	Demin water

Steam supply	
Inlet steam temperature	Saturated
Inlet steam pressure	2 bar g

Raw gas specification	
Inlet temperature	120°F / 48,9°C
Inlet pressure	11,65 psia / 0 psig
Inlet flow	Approx 188.000 lb/hr equvivalient to 12.250 kg/hr CO2 gas
Impurities based on average firgures from boiler 1 and 2	
CO_2	10,6 mol%
O_2	6,0 mol%
N_2, Ar and He	69,2 mol%
NOx	263 ppm
SO_2	9 ppm
H_2O	14,3 mol%

CO_2 product specification	
Outlet temperature	104 °F / 40 °C
Outlet pressure	75 psig / 5,2 barg
Outlet flow	12.250 kg/h
CO2 Purity	98,5 [% v/v]
H2O	1,5 [% v/v]
Oxygen, Nitrogen, Argon	-

Utility Requirements

All consumption figures are based on 100% plant load.

Power consumption

Chemical consumption	Consumption [lb/h]
MEA (Monoethanolamine)	Approx. 16
Soda (Na_2CO_3)	Approx. 9
Sodium carbonate solution	Approx. 175

Water consumption	Consumption [m^3/h]
Cooling water circulated	Approx. 500
Scrubbing water make up, demin water	Approx. 0,35

Steam consumption	Consumption [lb/h]
Steam saturated (2 bar g)	Approx. 30.000

Solid consumption/waste	Unit [lb]
Activated carbon (MEA-filter) – every 2000 hr.	Approx. 2.900

Gasous waste	Unit [lb/h]
Exhaust gas from absorber	Approx. 100.000

Liquid waste	Unit [lb/h]
Flue gas scrubber drain [1)]	Approx. 600
Reclaimer drain	Approx. 155

[1)] Water with traces of impurities present in the raw gas

Process Description

The plant, which is fully automatic and designed for around the clock operation, is based on the Econamine FG Plus[sm] technology. The absorption solvent is a 35 % by weight monoethanolamine (MEA) solution, mixed with an inhibitor for retarding corrosion and reducing MEA degradation.

The flue gas scrubber is used for removal of sulphur dioxide and any water soluble impurities. Sulphur dioxide is washed out by re-circulating a soda solution over the packed bed in the flue gas scrubber.

To over come pressure drop in the system, an induced draft fan (exhauster) is installed downstream of the flue gas scrubber.

The treated flue gas enters the extraction unit in the bottom of the absorber tower. The gas flows upwards through the packed bed sections of the absorber tower counter current to the circulated MEA solvent. The MEA solvent reacts chemically with CO_2 absorbing 80-90 % of the CO_2 in the incoming flue gas. Residue gas, mainly N_2 and O_2, is vented through the top of the absorber. In order to avoid MEA and water loses to the atmosphere, residue gas leaving the absorber is cooled in a wash section where entrained MEA are removed and returned to the absorber. Due to the chemical reaction with MEA the elevated CO_2 content will create additional heat and to control the temperature an intercooler section is installed in the bottom of the absorber tower.

The rich MEA solvent (CO_2 saturated) is pumped from the bottom of the absorber to the top of the stripping tower. It is preheated in the lean/rich solvent cooler before entering the top of the stripping tower. In the stripping tower the rich MEA solvent is further heated in a re-boiler by means of low pressure steam and the chemically bound CO_2 is released from the MEA solvent as a result of the increase in temperature.

From the re-boiler the lean MEA solvent is returned to the absorber tower through the rich/lean solvent cooler. The lean MEA solvent is cooled in two stages, first by the counter flowing rich MEA solvent in the rich/lean cooler and finally, before returning to the top of the absorber, by cooling water in the lean MEA cooler.

A part of the lean MEA solvent is led through a carbon bed in order to remove solution contaminants.

From the top of the stripper tower the CO_2 gas is transferred to the water scrubber where the gas is cooled and possible carry over of MEA is washed out before entering the compressor unit. After compression the gas cooled in an after cooler and water is removed.

To maintain the highest possible absorption capacity of the MEA solvent, contaminants, such as heat stable salts, are removed in a re-claimer. The re-claimer is operated as a batch process. Heat stable salts are removed by boiling of the MEA

solvent with steam. The heat supplied to the re-claimer will replace the heat for the stripping process, meaning the overall steam flow is kept on a constant rate. The waste from the re-claimer must be removed after each reclaiming.

For detailed overview of process flow and design data, please refer to the enclosed Process Flow Diagram.

Basic Scope of Supply

Our quotation consists of the following main equipment:

0112 Flue gas scrubber

Flue gas scrubber installed for cleaning and cooling of the flue gas.

The scrubber tower is equipped with distributor plates, ceramic/stainless steel tower packings and liquid level gauge. Furthermore the unit includes a re-circulation pump and a flow meter for measuring of incoming flue gas.

Tower:

- Material — Stainless steel AISI 316
- Manufacturer — UE sub supplier

Pump:

- Manufacturer — Flowserver

Flowmeter:

- Manufacturer — Yokogawa

0112a Soda dosing unit

Soda dosing unit, consisting of a soda solution mixing tank with agitator and automatic dosing pump, controlled by a pH sensor mounted in the scrubbing water line.

Mixing tank

- Material — Polyethylene
- Manufacturer — UE sub supplier

0113 Exhauster

Exhauster for overcoming pressure losses in the system. The unit consist of a centrifugal type exhauster, provided with AC motor. The exhauster is mounted on vibration absorbers and connected to the flue gas pipe with flexible pipe connections.

Exhauster:

- Type — Centrifugal
- Casing Material — Stainless steel AISI 304
- Manufacturer — Witt & Sohn, or similar

0114 Absorber tower

Absorber tower for the absorption of CO_2 in the MEA solvent. The tower is equipped with distributors for efficient distribution of MEA solvent over the packed bed sections. Packed beds are made of polypropylene random type tower packings. The tower has a demister in the top to avoid any emission of MEA to the atmosphere.

Ladder and platform's for easy access to instruments and inspection points.

Tower

- Material — Stainless steel
- Manufacturer — UE sub supplier

0114a Absorber inter cooler

To increase MEA loading and control reaction heat in the absorber a side stream of the solvent is pumped through a water cooled heat exchanger and led back into the absorber.

Intercooler

- Cooling media: — Cooling water
- Type — Plate and frame
- Material — Plates/frame, AISI 304/316 / Carbon steel
- Manufacturer — Alfa Laval or similar.

Circulation pump

Manufacturer — Flowserve

0114b MEA solvent pumps

Two sets (one set as standby) of centrifugal pumps for transferring MEA solvent between absorber and stripper.

Rich MEA solvent pump

- Manufacturer — Flowserve

Lean MEA solvent pump

- Manufacturer — Flowserve

0114c MEA solvent coolers

MEA coolers, consisting of two plate heat exchangers. One lean/rich solvent cooler, where the rich MEA solvent is preheated (while cooling lean MEA solvent) before entering the top of the stripping tower; and one water cooler for additional cooling of lean MEA solvent with cooling water. The cooling water inlet is supplied with a control valve for reducing the cooling water flow.

Lean/rich solvent cooler

- Cooling media: — Rich MEA solvent
- Type — Plate & frame
- Material — Plates SS
- Material — Frame Carbon steel
- Manufacturer — Alfa Laval or similar.

Water cooler

- Cooling media: — Cooling water
- Type — Plate & frame
- Material — Plates SS

- Material — Frame Carbon steel
- Manufacturer — Alfa Laval or similar.

0114d MEA solvent filter

A partial stream of MEA lye indicated by a flow indicator is led through an activated carbon filter with pre- and after filter. For regeneration of the filter a valve arrangement is mounted for back flushing with clean water.

MEA filter

- Capacity — 10% of main flow
- Material — Carbon steel
- Manufacturer — UE sub supplier

0114e Top cooler

Top cooler, consisting of a stainless steel plate heat exchanger for cooling of water which is supplied to the absorber wash section. The top cooler is equipped with two water circulation pumps (one as spare).

Top cooler

- Cooling media: — Cooling water
- Type — Plate & frame
- Material — Plates SS
- Material — Frame Carbon steel
- Manufacturer — Alfa Laval or similar

Water circulation pump

- Manufacturer — Flowserve

0115 Stripper tower

Stripper tower for stripping CO_2 from MEA solvent. The tower is complete with distributor, internals and stainless steel tower packing. The tower will be supplied without insulation, platforms and ladders. The stripper inspection holes can be reached from absorber platforms.

Stripper tower

- Material — Stainless Steel AISI 304/316
- Manufacturer — UE sub supplier

0103 MEA Reboiler

Reboiler plate heat exchanger design with, condensate drain and two return pumps one as stand-by.

Heat exchanger

- Heating media: — Steam
- Type — Plate & frame / Plate & shell
- Material — Plates SS
- Material — Frame/Shell Carbon steel
- Manufacturer — Alfa Laval/Vahterus or similar

0104 Reclaimer

During plant operation the MEA will be degraded by presence of especially O_2, SO_2 and NO_2 but also from reaction with CO_2 which will result in the formation of heat stable salts. In order to keep the performance of the MEA solution, these heat stable salts needs to be removed from the solution. This is done by evaporation in the reclaimer. The reclaiming process is done continuously and is fully automatic.

0115a Gas cooler

Gas cooler for cooling CO_2 gas leaving the stripper tower. The gas is saturated with water and the condensate will be led back to the MEA system. The cooler is a plate heat exchanger mounted in conjunction with a liquid separator made of stainless steel in which a water trap and a demister is included. A condensate pump will return the condensate to the stripper/absorber tower.

Gas cooler

- Cooling media: Cooling water
- Type Plate & frame / Plate & shell
- Material Plates SS
- Material Frame/Shell Carbon steel
- Manufacturer Alfa Laval/Vahterus or similar.

0123 Water scrubber

Gas scrubber for cooling of the CO_2 gas and removal of possible MEA carry over. The scrubber tower is equipped with distributor plates, stainless steel tower packings and liquid level transmitter. Furthermore the unit includes two re-circulation pumps (one as stand-by) and a heat exchanger for scrubbing water.

Tower:

- Material Stainless steel AISI 304
- Manufacturer UE sub supplier

Pump:

- Manufacturer Flowserve

Heat exchanger:

- Cooling media: Cooling water
- Type Plate & frame / Plate & shell
- Material Plates SS
- Material Frame/Shell Carbon steel
- Manufacturer Alfa Laval/Vahterus or similar.

0201 CO_2 compressor unit

CO_2 compressing unit consisting of oil lubricated screw compressor and main motor. The compressor can operate in range of 40...100% of full load capacity. The compressor unit is equipped with water cooled oil cooler, two

electrically driven lubricating pumps (one as stand-by), high efficient oil separator incl. coalescing type oil filter with automatic drain, single oil filter, suction strainer and check valve to prevent back flow.
Initial filling of food grade lubricating oil is included in scope of supply.

Compressor

- Compressor type — To be informed
- Manufacturer — Mycom

Oil-cooler

- Cooling media: — Cooling water
- Type — Shell and tube
- Material — Shell/tube, Carbon steel/Carbon steel
- Manufacturer — Mycom

For continuous monitoring of the compressor a vibration sensor is installed.

If continuous turndown rate below 30% (approx. 3.675 kg/h) is needed then the compressor must be controlled be a variable speed drive VSD.

0201b After cooler

After-cooler installed for cooling of the CO_2 after the compressing process:

After cooler

- Cooling media: — Cooling water
- Type — Plate & framel
- Material — Plates SS
- Material — Frame Carbon steel
- Manufacturer — Alfa Laval or similar.

0500 Cooling water system

The cooling water to the various components of the plant is supplied by the client at conditions as specified in the process design section.

1701 Electrical scope

Junction Boxes

One junction box per skid with a terminal strip for connection of instrumentation is considered. Distributed IO-modules are not included.

Junction boxes are as Rittal enclosure type AE in stainless steel (304). IP66 (NEMA 4). Size considered (600x600x210mm).

Made according to UL508A and UL listed.

Junction boxes are not equipped with heater or cooler.

Skid installation
Wiring of instruments and valves at the skids to their respective junction box is done with rigid galvanized conduits. For termination to the instruments flexible conduits are considered. Conduit installation is provided according to NEC and US regulations.

Motors, heaters and other loads are not pre-wired at the skids, wiring must be done on site.

None skid mounted instrumentation must be installed and wired on site.

Control system – Not Union scope
The control system is not included in Union scope of supply.

Documentation delivered by Union

- Motor and Consumer list.
- List of Instruments and valves.
- Documentation of junction boxes.
- Control description provided in Grafzet.
- Range and Setpoint / Alarm list.
- Cause effect diagram.

2101 Supervision

After buyer has completed the installation of the plant, a Union Engineering Supervisor will verify that the installation has been carried out in accordance to the Union Engineering installation and erection instructions. After approval of the installation work, the Union Engineering supervisor will carry out plant commissioning, start-up and training of local staff.

On site verification and commissioning (testing) consists of:

- Line walk of complete plant installation.
- Checking PLC input/output according to I/O-list.
- Manual plant operation test.
- Wet test.
- Automatic plant operation test.
- Plant performance test including:
    - Plant production capacity.
    - Plant product quality (test equipment not supplied by Union).
    - Plant utility consumption.
    - Plant chemical consumption.

The proposal includes supervision for a total of 20 working man weeks. One or more supervisors may be at the site at the same time. The proposal includes all cost for journey and stay of the supervisors.

The number of days paid for is counted from departure from any Danish Airport to arrival at the same place.

The charge is based on an 8 hour day and a 6 days week.

In case of overtime and work on Sundays, extra charges will have to be made. Total charge per extra hour will amount to EURO: 173.00 per hour Sickness days are considered as unemployed days. Withholding taxes, if applicable, are not included in any charges stated for supervision / commissioning.

If the supervision cannot be complete within the above mentioned time frame and the delay is due to circumstances for which the supplier cannot be held responsible, extra supervision will be charged according to the Union Engineering standard supervision conditions.

It is required that a 1mbit internet connection is available on site for online support for the commissioning engineer and remote update of PLC program. The internet line must be available in the control panel.

Optional Scope of Supply

1732 Spare Parts

Spare parts for start-up and two years' normal operation are carefully selected based on our sub-suppliers recommendations as well as our own experience throughout more than 25 years in the CO_2 business.

All spare parts supplied are individually tagged for fast and reliable identification.

Exclusives

Our offer consists of the above only and thus not:

- Pipes, wiring and fittings apart from our installation unless specified in main scope of supply
- Buildings and foundations and any engineering for same.
- Final coating/painting (on site) of process towers and connection piping
- Pipes for connection between skids and field mounted equipment, as well as pipe racks and pipe supports unless specified in main scope of supply
- Insulation materials for pipes erected on site unless specified in main scope of supply
- Cables, cable trays and wiring of all external instruments unless specified in main scope of supply
- Re-wiring of skid mounted instruments which have been disassembled prior transportation unless specified in main scope of supply
- Motor starters
- Panels
- Circuit brakers
- Contactors
- Switches
- Variable Speed Drives, VSD
- Earthing of the panels and the equipment
- Filters to reduction of harmonic distortion from VSD drives to the electrical network
- Scrubbing and cooling water make-up supply unless specified in main scope of supply
- Water softening plant unless specified in main scope of supply
- All insulation material and insulation work which have to be done on site
- Expenses in relation to installation like civil works, water, electricity etc.
- Local installation
- Approval by local authorities
- Import licences, local taxes
- Chemicals for cleaning of pipes and equipment
- Power supply cable (one point to plant)
- Waste water drains
- Withholding taxes, if applicable, are not included in any charges stated for supervision / commissioning.

Equipment Supplier List

To be considered as preliminary.

Equipment	Manufacturer
Liquid Centrifugal pumps	Flowserve
Booster Blower	Continental/Gardner Denver/Witt & Sohn
CO_2 compressor	Mycom / Neumann & Esser
Plate heat exchangers:	Alfa Laval / APV / Vahterus
S/T heat exchangers	APL / YPV China
Pressure vessels	Union Engineering approved manufacturer
Process towers	Union Engineering approved manufacturer
Filters	Ultrafilter / Domnick Hunter or similar
Valves:	
Ball valves	Tyco
Check valves	Danvalve / Gestra
Butterfly valves	Tyco/Keystone
Safety relief valves	Danfoss/ARI/Freze/Niezgodka/Henry
Control valves	Masoneilan
Solenoid valves	ASCO
Reduction valves	IMI Norgren / Danfoss
Instruments:	
Flowmeters	Houdec / Kytola
Temperature indicators	Wika or similar
Pressure indicators	Wika or similar
Temperature switches	Danfoss or similar
Pressure switches	Danfoss or similar
Temperature transmitters	Yokogawa
Pressure transmitters	Yokogawa
Flow transmitters	Yokogawa
Level transmitters	Yokogawa
Electrical equipment:	
Motors	Siemens / Toshiba

APPENDIX A

Documentation

The following documentation is supplied with the plant.

Documentation for Vessels:

- Certificate of conformity incl. final assessment report.
- As-build drawing.
- Material certificates.
- IOM (Instruction, operation & maintenance) Manual

Documentation for Heat Exchanger:

- Instruction-, operation & maintenance manual.
- Manufacturing drawing / As-build drawing incl. part list.

Documentation for Valves:

- Instruction- / operating- / maintenance manual.

Documentation for Safety Valves:

- Instruction- / operating- / maintenance manual.
- Pressure setting certificate.

Documentation for Instruments:

- Instruction- / operating- / maintenance manual.
- Calibration certificates.

Documentation for pumps:

- Pump data sheet.
- Pump operating manual.
- Motor manual.
- Pump performance curves.
- Cross-sectional drawing with parts list.
- Outline dimensional drawing.

Documentation for piping:

- Pipe classification list.

Drawings and diagrams

- Process flow diagram
- P&I diagrams
- Part list
- Layout and foundation drawings
- Piping layout/arrangement (isometric)
- Piping layout/arrangement (isometric) of piping between skids
- Plant design (isometric)

Electrical documentation

- Main circuit diagrams
- Control diagrams
- Terminal strip diagram
- I/O list
- Cause and effect list
- Alarm shut down list
- Motor and consumer list

Manuals

- Installation manual (*)
- Operation and maintenance manuals
- Data books of all pressure vessels.

(*) The installation manual includes lay-out drawings, arrangement drawings and isometric pipe drawings to ensure correct installation of plant prior to arrival of Union Engineering Site Engineer thus minimising time consumed when starting up the plant.

Operator manual, all installation and maintenance manuals will be supplied in English language.

Manuals are supplied on CD-ROM and three hard copies

Attachment C – Solvay Boiler Cost Estimate

SOLVAY CHEMICALS, INC.
PARACHUTE BOILER PROJECT

BUDGET ESTIMATE **12/20/2012**

EQUIP. PO NO.	DESCRIPTION	BUDGET VALUE
	Materials	
03-001	Concrete Reinforcing (Rebar only, incl. piers)	$125,000
03-002	Concrete Embedded Items (Anchor Bolts, Curb Angle, etc)	$25,000
04-001	Culvert	$30,000
ST-001	Boiler Exhaust Stack	$82,500
TA-001	Blowdown Tank (35 psi)	$33,000
TA-002	Sulfite Tank (100 gal)	$2,750
05-001	Structural & Miscellaneous Steel (incl. grating, handrail, etc.)	$500,000
13-001	Concrete Block	$20,000
13-002	Siding & Roofing (incl. girts & purlins)	$170,000
13-003	Doors, Hardware & Finishes (Process & Elect. Bldgs.)	$30,000
DO-001 A&B	Roll-Up Doors (2)	$22,000
15-001	Piping Tie-Ins (incl. valves, fittings & shop fab.)	$113,210
15-002	Piping (incl. valves, fittings & shop fab.)	$220,000
15-003	Ductwork (w/ Expansion Joints)	$100,000
16-001	Ductbank PVC	$30,000
16-002	Electrical & Lighting - Fixtures, Cable, Conduit & Cable Tray	$157,000
17-001	Control Valves (7)	$50,000
17-002	Instrumentation - Cable, Conduit & Cable Tray	$96,000
	TOTAL	**$1,806,460**
	Equipment	
	Boiler Equipment Package (incl. Economizers) - Demo & Shipping only	$0
	Reconditioning Existing Boiler Equipment	$200,000
FN-001	Combustion Air Fan - Clarage (w/ 800 HP Motor)	$209,000
BR-001	Windbox/Burner/Damper/GasTrains - Coen (w/ FCV)	$420,000
BMS-001	Fyr-Monitor BMS/CCS Controls - Coen (w/ Control Panel)	$130,000
PU-001A&B	Boiler Feed Water Pumps - Sulzer (w/ 250 HP Motors)	$605,000
PS-001	Vertical Sump Pump - Warman (w/ 50 HP Motor)	$27,500
PD-001A	Sulfite Injection Metering Pump (w/ 1/3 HP Motor)	$2,750
PD-001B	Nexgard Injection Metering Pump (w/ 1/3 HP Motor)	$2,750
DA-001 A&B	Vane Dampers (2)	$79,200
AC-001 A&B	Beck Actuators for Vane Dampers (2)	$66,000
VA-001 A&B	ARC Valves for Boiler Feed Pumps (2)	$44,000
FN-002 A&B	Exhaust Fans (2, w/ 25 HP Motors)	$22,000
	HVAC Equipment (Electrical Bldg & MCC/Tech Room)	$40,000
SS-001	Safety Shower (w/ Eye Wash Station)	$2,750
HO-001 & HO-002 A&B	Monorails, Jib, Hoists & Trolleys (3)	$27,500
16-003	Electrical - Process	$736,000
17-003	Instrumentation & Controls - Process	$82,000
17-004	DCS Equipment & Upgrades	$122,000
SM-001	Exhaust Stack Monitor & CEMS Bldg.	$200,000
	Spare Parts	$150,000
	TOTAL	**$3,168,460**

SOLVAY CHEMICALS, INC.
PARACHUTE BOILER PROJECT

BUDGET ESTIMATE **12/20/2012**

EQUIP. PO NO.	DESCRIPTION	BUDGET VALUE
	Construction Contracts	
10-001	Piping Tie-In Construction	$245,265
10-002D	Demo & Site Prep	$100,000
10-002C	Culvert & Ductbank Construction	$100,000
10-002E	Electrical - Relocation	$50,000
10-003	Drilled Pier Construction (incl. concrete, 300 cu yd)	$270,000
10-004	Foundation Construction (incl. concrete, 800 cu yd)	$500,000
10-005	Mechanical & Structural Construction	$1,500,000
10-006	Piping Construction (incl. pipe supports)	$1,000,000
10-007	Piping & Equipment Insulation Construction (incl. insulation & cladding)	$300,000
10-008	Concrete Block & Electrical Building Construction	$150,000
10-009	HVAC Construction (incl. ductwork)	$40,000
10-010	Siding & Roofing Construction	$200,000
11-001	Electrical Construction	$134,000
11-002	Instrumentation Construction	$112,000
11-003	DCS Programming	$16,000
12-001	QA/QC, Testing (Structural and Mechanical)	$15,000
12-002	QA/QC, Checkout (Electrical and Instrumentation)	$15,000
	Misc. Material, Equipment & Construction Requisitions	$20,000
	TOTAL	**$4,767,265**
	TOTAL EQUIP, MAT'L & CONTRACTS	**$9,742,175**
	Services Contracts	
	Solvay Engineering & Start-Up	$225,000
	ECMS - Preliminary Engineering -New & Future (Phase I)	$105,000
	Solvay - Permitting	$147,754
	EDA - Preliminary Electrical/Instrumentation Engineering -New & Future (Phase I)	$69,480
	Coen - FD Combustion Fan Engineering	$60,000
	ECMS - Detailed & Final Engineering - New (Phase IIA)	$320,000
	ECMS - Detailed & Final Engineering - New (Phase IIB)	$100,000
	EDA - Detailed & Final Electrical/Instrumentation Engineering - New (Phase II)	$40,000
	ECMS - Procurement Support - New (Phase III)	$80,000
	ECMS - Construction Management (Phase IV)	$480,000
	TOTAL	**$1,627,234**
	SUBTOTAL - BEFORE CONTINGENCY	**$11,369,409**
	SOLVAY - Overhead (0%)	$0
	Contingency (10%)	$1,136,941
	TOTAL CAPITAL COST	**$12,506,350**
	TOTAL PROJECT COST	**$12,506,350**